Chapter 15

HELICOPTERS, STOLs, VTOLs AND UAVs

Objectives

Identify at least two heavy-lift helicopters.
Identify at least two light-lift helicopters.
Define STOL and VSTOL.

Helicopters

The helicopter has only been with us since the end of World War II. We have already mentioned many of its uses in agriculture, heavy lifting and hauling, and other commercial uses. Today, the big push in civil aviation helicopters is into the executive/business aviation fields.

Helicopters have always had several drawbacks, which have made them unattractive to civilian operators. These shortcomings include high maintenance costs, vibrations and high noise levels, and slow cruise speeds. Advances in technology have reduced all of these shortcomings and have practically eliminated some of them.

Turbine engines with greater power for a given weight have increased the range, speed and payload in modern helicopters. Better engineering has produced gearboxes with fewer moving parts and gears that run with a closer fit. This has reduced noise and vibration and has lowered maintenance costs as well. New bearings and bushings have further reduced the noises and vibrations, and more soundproofing has been added to the engine compartment and cabin.

Building them out of fiberglass reduced maintenance costs on the rotor. The latest trend is toward the use of composite materials in rotor blades. The composites have the advantage of being much stronger and lighter than earlier materials.

Military

Throughout this part, we have said that the category an aircraft is placed into depends entirely upon its use. Using this logic, there are only two US helicopters that are limited strictly to military use– the Bell *AH*-1 *HueyCobra* and *AH*-64 *Apache.*

Bell *AH*-1 *HueyCobra*. The *AH*-1 was designed specifically as an armed attack helicopter and made its first flight in September 1965. There are two basic aircraft in the *AH*-1 series, the single-engine *AH*-1*G* and the twin-engine *AH*-1*J*.

The *HueyCobra* is very narrow (58 inches) and has a low silhouette which makes it harder to hit with ground fire. The gunner sits in front of the pilot and both are protected by armor. The pilot sits higher than the gunner to see over the gunner's shoulder.

In addition to a chin turret housing machine guns or grenade launchers, the *AH*-1 can carry cannons, rockets or machine guns on its stub wings. The *AH*-1 is very fast for a helicopter (200 mph) and has a maximum range of 350 miles.

***AH*-64.** In 1977, the US Army selected the Hughes *AH*-64 as its new advanced-armed helicopter. In 1984, Hughes Aircraft Company was purchased by McDonnell-Douglas so the aircraft is now the McDonnell-Douglas *AH*-64. The *AH*-64 uses experience gained in the Vietnam War and is designed and produced as an *AH*-64 attack helicopter, which can survive on the battlefield. The *AH*-64 carries a crew of two (pilot and gunner) in a heavily armored cabin. Its main armament consists of a rapid-fire, 30-mm cannon and can carry up to 16 TOW or Hellfire rockets or 76 2.5-inch rockets on its stub wings.

The *AH*-64 is larger than the *AH*-1. It flies about 180 mph and has a range of over 600 miles. First deliveries were made to the Army in 1984.

All other US helicopters are available to both the military and the civilian communities. Classifying them is very difficult because helicopters are designed to perform many tasks. For our purposes, we

AH*-64*A Apache *(Boeing Photo)*

will group them into heavy-lift and light-lift helicopters. Our dividing point between heavy-lift and light-lift will be at a useful load of 4,000 pounds. Any helicopter with a useful load of less than 4,000 pounds will be considered a light-lift helicopter. Any helicopter with a useful load of over 4,000 pounds will be considered heavy-lift.

If the useful load of a helicopter is given as 6,000 pounds, this includes the weight of the gas and oil, the crew and payload. If the crew weighs 275 pounds and the payload weighs 4,000 pounds, the maximum amount of fuel and oil that can be carried on this mission is 1,725 pounds (6,000 minus 4,275).

Heavy-lift Helicopters

The largest and heaviest helicopters were designed for military use. Many are now coming into civilian use, mainly from purchase of surplus military aircraft. Helicopter manufacturers are now beginning to look at the civilian market for sales of new, large helicopters.

Boeing *Vertol CH*-47. The *CH*-47 *Chinook* is a twin-rotor, heavy-lift helicopter powered by two turbine engines. The *Chinook* has been produced in three models with the major differences being in the power plants and rotor systems. A fourth model, the *CH*-47*D*, is a remanufacture of earlier models into the newer version. The *CH*-47*A* was powered by two 2,200-horsepower turbines: the *CH*-47*B* by two 2,850-horsepower turbines and the *CH*-47*C* by two 3,750-horsepower turbines.

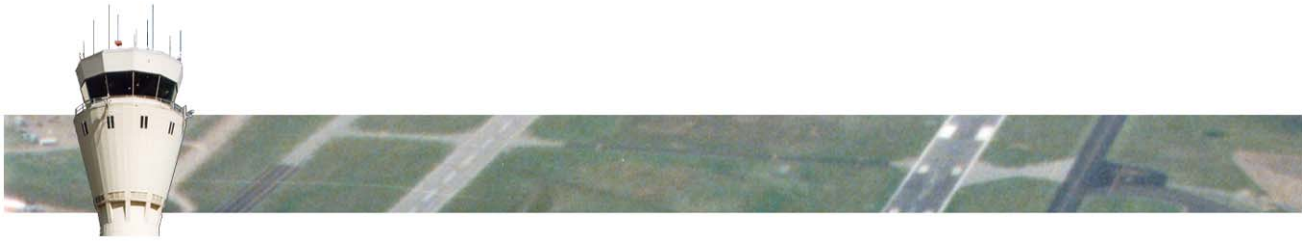
The *CH*-47*C* can carry up to 44 passengers and a crew of three. Its useful load is 25,257 pounds, and as much as 23,100 pounds can be carried on the external hoist. With a full useful load, the *Chinook* has a maximum range of 365 miles. The maximum speed of the *CH*-47*C* is about 185 mph, but its normal cruising speed is about 150 mph.

Boeing *Vertol* is building a civilian version of the *Chinook*, which they call the *Model* 234. One market they are hoping to attract is the offshore oil rigs. The large payload and seating for up to 44 passengers will make the *Model* 234 useful for delivering people and supplies to these remote sites.

Boeing *CH*-47 *Chinook* *(EAA)*

Coast Guard *HH*-60*J*

Boeing *Vertol CH*-46. This large twin-rotor helicopter is used by the US Navy and the US Marine Corps as a transport helicopter for getting supplies from shipboard to troops on shore. The *CH*-46 *Sea Knight* can carry 25 combat troops or 4,000 pounds of ammunition and supplies over a combat radius of 115 miles. The civilian version, called the *Model* 107, has been used by helicopter airlines for transfer of passengers between airports and from airports into the cities.



Sikorsky *HH*-3. Twin 1,500-horsepower turbine engines power both the *HH*-3*E* and the *HH*-3*F*, which gives them a maximum speed of 160 mph. The *HH*-3 is produced in two models, the *HH-3E Jolly Green Giant* for the US Air Force and the *HH-3F Pelican* for the US Coast Guard. Both are used for search and rescue.

The *Jolly Green Giant* won its fame during the Vietnam War where it was used for rescue of downed pilots and other troops in need of emergency evacuation. For these combat rescue missions, the *HH*-3*E* is equipped with armor, self-sealing fuel tanks, an aerial refueling probe and machine guns for protection. The *HH*-3*E* can carry up to 25 passengers or 5,000 pounds of cargo. Its hoist can lift up to 6,000 pounds.

In 1967, two *HH*-3*E*s made the world's first nonstop transatlantic flight by helicopter. They were refueled nine times during the 4,270-mile flight from New York to Paris.

The *HH-3F Pelican* is similar to the *Jolly Green Giant* except for the lack of armor, self-sealing tanks and machine guns. The *Pelican* has additional advanced electronic navigational equipment for over-water flights. The *HH*-3*F* is amphibious and can be landed on water if necessary.

Sikorsky *CH*-53 (*HH*-55). This is a very large, heavy-lift helicopter built for use by the US Navy, US Marine Corps and the US Air Force. The Navy and Marine Corps use the *CH*-53 for troop transport, cargo hauling and minesweeping. The *CH*-53 can carry 55 fully-equipped combat troops, two jeeps or a 105-mm howitzer. There were 265 *CH*-53s built for the Navy and Marines.

The Air Force *HH*-53*B*s and *HH*-53*C*s were delivered to the Aerospace Rescue and Recovery Service for use in the same types of missions as the *HH*-3*E*s. The *HH*-53 can pick up 20,000 pounds with its hoist. The *HH*-53*B/Cs* are all being converted to *MH*-53*J*s, which are equipped for night search and rescue using special infrared scanners, low-light television and radar systems linked to an airborne computer which permits operation at night.

Sikorsky *CH*-54 *Skycrane.* This aircraft is one of the largest helicopters in the world and holds several world records for its lifting ability. It is also one of the most widely recognized because of its strange shape. The *CH*-54 is not designed to carry anything internally except the crew. All of its cargo is carried externally in specially built containers slung under the *CH*54 between the landing gear. This arrangement makes the *CH*-54 look like a giant dragonfly. The *Skycrane* can lift bulldozers, road graders and armored personnel carriers. In Vietnam, they were used to recover more than 350 damaged aircraft. A special personnel van, which holds 87 combat troops, is also available.

The 964 is the commercial version of the *Skycrane.* Several logging companies and oil exploration companies use them.

Bell *UH*-1. The *UH*-1 *Hueys* and *Iroquois* are the most common helicopters in use by the military. The Army and Marine Corps are flying more than 4,000. Their civilian counterparts (204, 205, 212 and 214) are also the best selling helicopters in the *UH*-1 civilian market. They are just the right size to accomplish most transportation and hauling chores. They are also very rugged and reliable.

For our example of the *UH*-1 series, we will discuss the *UH*-1*N*, also called the *Bell* 212. This aircraft is a twin-engine aircraft capable of carrying a pilot and up to 14 passengers or 4,500 pounds of cargo. Its hoist is rated at 3,400 pounds. Another version, with larger engines, is available which can carry 5,600 pounds or lift 5,000 pounds with its hoist The *UH*-l*N* has a cruising speed of about 115 mph and a range of about 250 miles.

Sikorsky *UH*-60*A*. This is the newest US Army helicopter. It was selected as the Army's new Utility Tactical Transport Aircraft System (UTTAS) to replace some of the older *Hueys*. The *UH*-60*A* is much faster than the *Huey* and cruises at about l50 mph.

The Army uses the *UH*-60*A Black Hawk* for transporting troops and supplies on the battlefield. The *Black Hawk* carries a pilot, copilot, 12 troops or 9,300 pounds of cargo. It can lift 8,000 pounds with its hoist.

UH*-60*A Black Hawk

The Navy selected another version, the *SH*-60*B*, as its light airborne multi-purpose System (LAMPS) helicopter. The LAMPS will be used by the Navy for antisubmarine warfare, antiship surveillance, search and rescue, medical evacuation and general transportation.

The Air Force version of the *Black Hawk* is the *MH*-60*G Pave Hawk*. These helicopters are used for night operations and night search and rescue missions. They are equipped with low-level navigational systems, improved communications and weapons systems.

Sikorsky is also building two civilian versions of the *UH*-60. They are called the *S*-70*B* and the *S*-76. Their performance capabilities are shown here.

Light-lift Helicopters

	S*-70*B	***S*-76**
Crew	pilot, copilot + 12	pilot, copilot + 12
External lift	12,000 lbs	13,500 lbs
Max speed	193 mph	193 mph
Range	460 miles	460miles

The light-lift helicopters are used in the military for observation and transportation of personnel. In the civilian community, they are used as executive transport and for many commercial uses such as crop dusting, construction, and hauling personnel and light cargo.

In the United States, Bell Helicopters, Textron and Robinson Helicopter Company are the leading light-lift helicopter manufacturers. McDonnell-Douglas Helicopter Company, Enstrom Helicopters and Schweizer Aircraft Corporation also produce light helicopters, but in quite small numbers. McDonnell-Douglas and Schweizer have bought out Hughes Helicopter Company.

Bell 206 *Jet Ranger*. This aircraft is produced in four versions and is the most popular light-lift helicopter built in the United States. More than 7,000 have been produced and more than 4,600 of these have been delivered to civilian customers. The military version is called the *OH*-58*A Kiowa*. The *Jet Rangers* are powered by a single-turbine engine of either 317 horsepower or 460 horsepower depending on the version. There is room for two or three passengers besides the crew. The useful load is up to 1,600 pounds, and the *Jet Ranger* II has a cruising speed of 135 mph and a range of 350 miles.

Companies supplying offshore oil platforms use helicopters in the 206 series. These aircraft are used to transport people and supplies, to and from platforms that are as much as 150 miles from shore.

Bell 222. This aircraft utilizes the latest technology to produce a fast, quiet, long-range helicopter. The 222 is aimed at the executive aircraft market, as well as other commercial uses. It carries up to 10 passengers or 2,700 pounds of useful load. Its hoist is rated at 4,000 pounds. The twin 600-horsepower turbine engines give the 222 a top speed of 180 mph and a range of about 400 miles.

McDonnell-Douglas 500*D*. This aircraft is the commercial version of the *OH*-6 *Cayuse* helicopter used by the Army. There are about 2,500 *OH*-6s being used as light observation helicopters. There are four models of the 500 available, the *C* model with a 317-horsepower engine and the *D* model with a 420-horsepower engine. The 500*D* carries a pilot and four passengers or about 1,600 pounds of useful load. The 500*D* has a range of about 300 miles and cruises at about 150 mph. The *E* and *F* models have replaced the *D* model as the standard model. The *E* model is widely used by law enforcement agencies including the US Border Patrol.

Sikorsky *S*-76. Another helicopter, which was developed specifically for the civilian market, is the Sikorsky *S*-76. Much of the new technology developed for the *UH*-60*A* is used in the *S*-76. It is aimed at the executive aircraft market and is available in several plush interiors. The *S*-76 is powered by two 700-horsepower turbines that give it a maximum cruising speed of 160 to 170 mph and a range of up to 450 miles.

Sikorsky has used the latest in soundproofing and antinoise, antivibration technology to make the *S*-76 one of the smoothest and quietest helicopters ever built. The *S*-76 is also designed as an instrument flight rules (IFR) helicopter, which allows it to fly in all, but the worst types of weather. More than 800 have been ordered and 650 have been delivered to customers in 23 countries.

***Sikorsky S*-76**

Other Light Helicopters. There are three other US light helicopters, which we will discuss before looking at some foreign-made aircraft. The closest thing to helicopters for personal use are the small aircraft manufactured by Brantly-Hynes, Enstrom and Schweizer. All three of these aircraft utilize reciprocating engines rather than turbines. These are just about the only helicopters still being manufactured with piston engines.

The Brantly-Hynes *H*-2 is a two-place helicopter powered by a 180-horsepower reciprocating engine. The *H*-2 has a useful load of 670 pounds, cruises at about 100 mph and has a maximum range of 250 miles

Enstrom Helicopter Corporation makes four models of small helicopters, all of which are three-place aircraft. They are all powered by 205-horsepower reciprocating engines, and in two of the models, the engines are turbocharged. The Enstrom 280*C* has a useful load of 850 pounds and cruises at about 100 mph. The range with maximum fuel is about 250 miles. Enstrom uses fiberglass and aluminum exclusively in its construction.

Schweizer Helicopter builds a civilian version of the small, reciprocating-engine helicopter that was developed by Hughes Aircraft for pilot training by the Army. This aircraft, designated the 300*C*, is a three-place aircraft which cruises at about 90 mph and can carry a useful load of 1,000 pounds for 200 miles.

Foreign-built Helicopters

Three foreign manufacturers are dominant in the manufacture of helicopters. They are Aerospatiale of France, Messerschmitt-Bolkow-Blohm (MBB) of Germany, and Agusta of Italy. Aerospatiale is far larger than the other two and sells many times the aircraft as MBB and Agusta combined.

Aerospatiale. This is the national aerospace industry of France, and it is currently producing 10 different models of helicopters. They range in size from the five-place Gazelle to the 22-place *Puma*.

The most popular Aerospatiale helicopters in the United States are the seven-place *Alouette* III and the *Puma*. *A* new helicopter, the *SA* 365*N Dauphin* 2, is also becoming popular, particularly with the oil platform people. The *Dauphin* 2 is competitive with the Bell 222.

Agusta. This Italian company markets one helicopter, the 109*A Mk* II, which is imported into the United States by the Atlantic Aviation Corporation. The 109*A Mk* II is a light-haul, twin-turbine helicopter, which is being advertised as a high-technology competitor of the Bell 222 and the Sikorsky *S*76. The 109*A* can carry up to eight people or 2,400 pounds of useful load. It cruises at about 175 mph and has a range of about 350 miles. There are about 30 of these helicopters imported into the United States each year.

MBB. Marketed by MBB Helicopter, Inc., the *MBB BO* 105 *CBS* light helicopter is imported from West Germany. The *BO* 105 is a twin turbine-powered aircraft with a useful load of 2,300 pounds. It can lift 2,000 pounds with its external hoist. The range (300 miles) and speed (150 mph) are about the same as other light twin, turbine-powered helicopters. In addition to being used as an executive aircraft, the *BO* 105 is popular for use in supply of offshore oilrigs.

Compound and Hybrid Helicopters

Before considering STOL and VTOL aircraft, let us see what ideas have been offered for improving the helicopter. Basically, there are two concepts: compound helicopters and hybrid helicopters.

Compound Helicopters

The compound helicopter is simply a conventional helicopter with extra forward thrust provided by either a jet or propeller unit. The compound helicopter can have short wings or an airplane-like empennage (tail assembly) for control purposes. Experimental compound helicopters have been flown for a number of years. One compound gunship-type, the Lockheed *AH*-56*Cheyenne*, came close to being adopted for Army use, but was rejected because of its high cost. Among other features, it has a rigid rotor and blades that remain high in a flat plane, without the flapping mechanism common to most helicopters. It has a smaller control rotor mounted above the main rotor, as well as the standard side-thrusting rotor on the tail.

Higher rotation speed and higher forward speed are the advantages of this system. The *Cheyenne* has a top speed of 250 mph.

Compound helicopters are strong too. The Soviets had the biggest one, the *Mi*-12, also known as the *V*-12, or *Homer* to NATO. The *Mi*-12 lifts 55,000 pounds of payload vertically, or 66,000 pounds with a short takeoff run, to a service ceiling of 11,500 feet.

The *Mi*-12 lifts more than 88,000 pounds of payload to altitudes around 7,000 feet. It is a four-engine, two-rotor aircraft with the counter-rotating rotors mounted on the ends of wings on each side rather than fore-and-aft like most helicopters. The high wings are braced with struts and the span over the rotors is 219 feet 10 inches.

Soviet *Mi*-12

Hybrid Helicopters

A variety of advanced helicopter concepts can be lumped together as a category called hybrid helicopters. In general, these go further than compounds toward combining the airplane and helicopter. In one way or another, they attempt to solve the problem of using the rotor for vertical takeoff and landing without impeding forward flight. As long as that bulky, long-bladed, unstreamlined rotor structure sits spinning on top of the aircraft, both economy and performance will suffer.

The Prop Rotor. This aircraft would have an airplane-like basic structure but would have twin vertical engines powering long-bladed helicopter-type rotors called prop rotors out on the wingtips. After vertical takeoff, like the helicopters, the engines and prop rotors would swing (without stopping) from vertical to forward position and would become long-bladed, forward-thrusting propeller units. In a further refinement, the rotor blades would telescope to a shorter length as they swing forward for higher revolutions per minute (rpm) and more efficient forward thrust. For landing, the propulsion units would swing back up to the vertical position, while the blades extended converting the props back into rotors.

Research on this kind of aircraft was conducted at NASA Ames Research Center in California. This aircraft was a joint NASA/Army project called the *XV*-15 tilt-rotor research aircraft. The goals of the *XV*-15 project were to reach two or even three times the speed of a conventional helicopter, triple

the range of conventional helicopters, and reduce noise and vibration. The *XV*-15 flew for the first time in May 1977.

Bell Helicopter Textron built the *XV*-15. It is 42 feet long, has a 35-foot wingspan and is powered by two 1,550-horsepower turbine engines. Each engine turns a 25 foot-diameter rotor, but the engines are cross-connected so that if one engine fails the other will turn both rotors. Following a successful test program, Bell Aircraft and Boeing Helicopter began marketing the tilt rotor as the *V*-22 *Osprey.*

CV*-22 *Osprey

The US Navy and the US Air Force developed the *Osprey* into a tilt-rotor, multi-mission aircraft, which has the maneuverability and lift capacity of a helicopter and the speed of a fixed-wing aircraft. The Air Force version is designated the *CV*-22, the Navy version is designated the *HV*-22, and the Marine Corps' version is the *MV*-22.

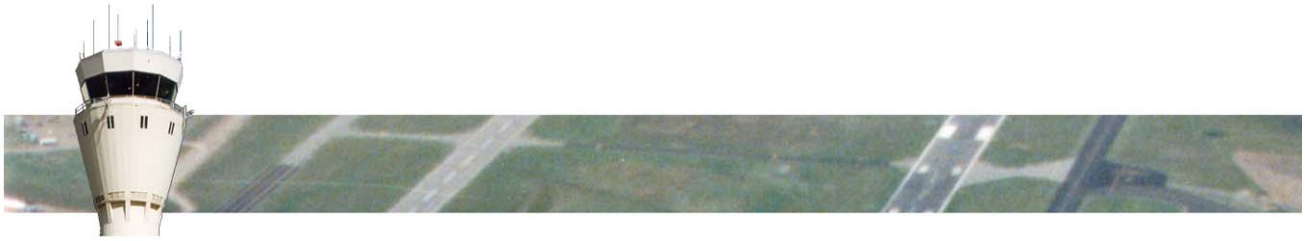
Short-takeoff-and-landing Airplanes

In previous chapters throughout this text, we have mentioned airplanes with unusually good short-takeoff-and-landing (STOL) capabilities. In describing these, we have used the term STOL. What is good STOL performance for a jet fighter would be very poor for a light, general aviation-type of plane. The Air Force has a precise definition of STOL, as given in the *US Air Force Glossary of Standardized Terms.* (The ability of an aircraft to clear a 50-foot obstacle within 1,500 feet of commencing takeoff and to stop within 1,500 feet after passing over a 50-foot obstacle when landing.)

Many light airplanes can clear a 50-foot obstacle in 1,500 feet total distance. To achieve this in heavier lifters or high-speed airplanes, however, requires advanced design of both engine and airframe. This is one of the big challenges of modern aviation technology.

The Value of STOL

There are differences of opinion as to whether STOL is worthwhile when the full vertical takeoff-and-landing (VTOL) capability is another goal being pursued. Most agree, however, that the pursuit of STOL is a worthwhile effort and will not be made obsolete by VTOL progress for many years to come. As things look now, STOL can be more easily combined with better all-around aircraft economy and performance. Full VTOL capability demands more engine weight, more fuel consumption, and less payload.



In war, there will always be situations in which STOL is not good enough and only VTOL airplanes or helicopters can be used. An example is rescuing a downed flyer from a jungle or supplying troops in battle. In other military situations, however, advanced STOL capability would be highly useful. Higher-performance STOL airplanes could use short, unprepared landing strips, and could transport personnel and supplies over long distances faster than present-day helicopters. STOL attack or fighter planes could be dispersed over many small military bases rather than a few large ones.

As for civil use, we have already spoken of the advantages of light general aviation aircraft being able to use numerous, small ill-equipped airports where airline service does not reach. NASA is currently engaged in STOL research for the benefit of both military and civil aviation. Study is being concentrated on noise control and engine-out performance (how well an airplane can perform if it loses the power of one of its engines). The noise factor is of particular interest for civil aircraft.

Some STOL Characteristics and Problems

Wings on STOL airplanes tend to be long in span and have considerable bulge or camber in the cross-section. (Those on the previously mentioned *OV*-10 *Bronco* are straight with absolutely no taper or sweepback.) Some STOL types have additional airfoil areas such as connecting tail planes between two rudders (as on the *OV*-10) or a connecting airfoil between high-mounted twin engines, which provide additional lift.

Engines are relatively powerful for the weight of the airplane. They provide extra thrust to help make up for the loss of speed built into STOL design. They are also especially efficient for takeoffs and landings. Hence, turboprop engines are favored for many STOL designs, but other successful STOL designs, such as the *C*-7 *Caribou*, feature reciprocating engines.

Additionally, the Soviets demonstrated the jet-lift STOL principle on some of their supersonic fighters. Retractable wing flaps have long been standard on conventional aircraft. Those on STOL aircraft tend to be larger or of special design. Slots in flap and wing surfaces add to lift. Ridges and fences across the wings also increase lift.

Slow STOL. One advanced feature of some STOL aircraft is the deflected slipstream. This is a system for spreading the backwash from the propellers evenly over the top of the wings to intensify the lifting effect. Thus, the aircraft can move forward at a slow speed while getting the same lift it would ordinarily get at a faster speed. Consequently, it would need less runway for takeoff and could also land at slower speeds, reducing landing distance and runway requirements.

A necessary safety feature on such an airplane is a system of interconnected or cross-coupled engines. If one engine fails, power from the remaining engine(s) is supplied evenly to all propellers.

Vertical-takeoff-and-landing Aircraft

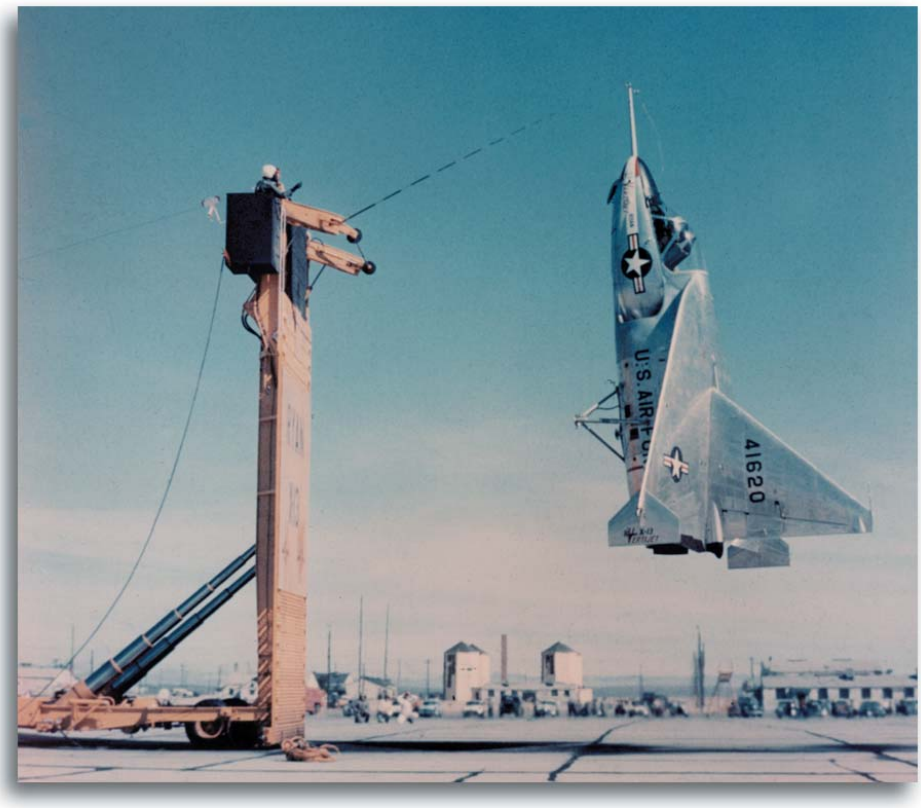
It seems but a simple hop from short takeoff and landing (STOL) to vertical takeoff and landing (VTOL), but in fact, the difference is considerable. One observer put it well when he said that our knowledge of how to achieve VTOL right now is about at the same point that general aviation knowledge

was in the early 1900s. We know what we want to do, but we still have a long way to go before we get where we want to be.

VTOL Principles

The search for VTOL capability has been going on with varying degrees of intensity since the 1940s. What we may call concentrated research into the matter started around the end of the 1950s. What is sought is a method by which an aircraft can achieve forward flight, like a conventional aircraft, but can also takeoff and land without any horizontal movement at all.

Many principles for such flight have been tested, and many successful test flights have been made. With the exception of the *Harrier*, however, no VTOL aircraft, either civil or military, have been put into common use in any country. In this section, we will mention some of the experimental aircraft because they represent variations of design toward a common goal. Most of them are no longer flying. However, they are interesting historically as well as for what we learned from them.



The Ryan *X*-13 was an early experiment in VTOL technology.
(San Diego Aerospace Museum)

VTOL capability is achieved through the application of Newton's Third Law of Motion, the one that says for every action there is an equal reaction in the opposite direction. As applied to VTOL, this means that the exhaust gas or air directed downward, toward the ground, results in aircraft movement upward. This same principle works in forward flight.

There are two ways to use this principle of action and reaction. We may either use the aircraft's main propulsion units to provide the vertical thrust or we may equip our aircraft with auxiliary units for that purpose. In aircraft with auxiliary units, these engines are turned off after they lift the aircraft off the ground and the main propulsion units have built up enough speed to provide conventional lift to keep the aircraft aloft. If the main propulsion units are used to achieve liftoff, other problems must be solved.

Two methods are available for using the main propulsion units. Either the exhaust from the engines is vectored (redirected) downward through special vents, as with the *Harrier*, or the entire propulsion unit turns, as with NASA's tilt-rotor research aircraft (TRRA). In the case of redirected exhaust, where the main engine provides VTOL lift, past experience has shown that very heavy engines are required. In the case of rotated propulsion systems (usually turboprop aircraft), designs often result in strange-looking aircraft on the borderline between VTOL airplanes and hybrid helicopters. Perhaps it would be convenient to consider jet and turboprop VTOL separately.

Turboprop VTOL

In a sense, turboprop VTOL aircraft could be called hybrid helicopters since they depend upon upward-aimed propellers for VTOL. Like the prop-rotor concept covered earlier, the propellers tilt straight upward for VTOL and forward for level flight. (They can also tilt upward for STOL.) The difference is that, in all positions, these propellers do not change length to become rotors, but remain short propellers. They must turn at high rpm with a heavy output of energy to accomplish vertical takeoff or soft-vertical landing.

Jet VTOL

There are various ways of accomplishing jet-lift VTOL. The jet engine can have a swiveling exhaust nozzle to provide vertical or horizontal thrust. Another way of shifting thrust between vertical and horizontal is to do it by means of shifting ducts inside the aircraft. The aircraft can have separate rigid-mount jet engines, some aimed horizontally and some aimed vertically, or the whole engine can pivot from horizontal to vertical position. There is also the jet-powered fan-in-wing VTOL principle. One aircraft can employ a combination of more than one of these principles.

The swiveling-nozzle principle is the one used in the world's only currently operational jet-lift VTOL aircraft, the *Hawker-Siddeley Harrier.* All the others are or were experimental aircraft. All have flown and all have accomplished VTOL under varying conditions. We will briefly describe them. The *Harrier* may or may not employ the best of these jet-lift principles. It is operational today because it works and because it meets a military need.

Fan-in-wing VTOL Principle. The fan-in-wing VTOL principle has been experimented with in both Germany and the United States. In the United States, it began as an Army project, then was transferred to NASA. The US aircraft, the Ryan XV-5*A*, mounted two jet engines high in the fuselage. These provided regular forward thrust, but some of the exhaust was ducted (turbofan fashion) to flat-lift fans in the wings for VTOL thrust. A third and smaller fan was located in the nose for pitch control. The *XV*-5*A* reached speeds of over 500 mph. One of the two prototypes crashed in 1965 and the other was damaged later during an emergency landing. The latter was rebuilt and modified as the *XV*-5*B* and was transferred to NASA for test use in 1968.

Combination Engines. The Lockheed *XV*-4 *Hummingbird* was a test vehicle flown at different times under Army and Air Force sponsorship. It had six jet engines, four vertically mounted, mainly for lift, and two horizontally mounted, mainly for thrust. Each set of engines, however, contributed to the other's effort by means of swiveling nozzles. By means of shifting ducts, the vertical engines added

thrust to the horizontal engines. The speed was around 400 mph.

The *Harrier*. The *Harrier*-or the *AV-8A*, as the Marines call it, has exceeded Mach 1 in a shallow dive and has achieved very close to sonic speed in level flight. In a trade-off to achieve VTOL, the *Harrier* sacrifices both top fighter performance and heavy-attack payload. Nevertheless, it is a warplane that can fight when others cannot. You will recall that the *Harrier* was first used in combat by the British during the Falkland Island crisis in 1982. It performed very well in both an air defense role and in providing tactical support to the British troops.

The *Harrier*'s VTOL ability comes from its single-turbofan Pegasus engine. The Pegasus has four swiveling jet nozzles, which can be aimed straight downward for VTOL, straight rearward for forward thrust, at varying angles downward for STOL and even sideways. In fact, since the nozzles rotate vertically through 98 rather than 90, the *Harrier* can point its nozzles downward and slightly forward and fly backwards at speeds up to 30 mph. It can fly sideways up to 70 mph. Small attitude-control jets in the wings are also fed by the central power plant.

AV-8 Harrier *(Boeing Photo)*

Unmanned Air Vehicles

Unmanned air vehicles (UAV) are small, pilot-less aircraft that perform missions which do not require a pilot onboard or which are considered too dangerous or politically unwise for manned flight. Such missions include long- or short-range reconnaissance over hostile territory, electronic surveillance, psychological warfare, destruction of enemy antiaircraft defenses or flying in environments contaminated with nuclear, biological or chemical contaminants.

Unmanned air vehicles have been in existence since World War I. These vehicles were used during World War II and in Korea, but it wasn't until the Vietnam War that they became widely used. There were 3,400 missions flown by UAVs during the Vietnam War with their widest use being for reconnaissance, electronic surveillance and psychological warfare. Israel also used UAVs against the Egyptians during the 1973 war and against Syria in 1982. During the Vietnam War, and by Israel against the Arabs, the aircraft were called remotely piloted vehicles (RPV) because they were "flown" remotely by a pilot either on the ground or in another aircraft. After the Vietnam War, the US Air Force lost interest in RPVs because they were difficult to control and were often unreliable.

In the 1980s, new technology, which had been developed for cruise missiles allowed unmanned aircraft to fly without being remotely piloted and the name was changed to unmanned air vehicles (UAV). Many of them have a mission pre-programmed into their guidance system so they can takeoff, fly the mission and return without any outside guidance. The USAF calls all of these aircraft UAVs regardless of whether they are remotely piloted or not. Other organizations still refer to remotely piloted vehicles as RPVs.

The missions of UAVs are classified as either nonlethal or lethal. Nonlethal missions are any missions where the UAV is not used to destroy some type of target. These include all the uses we have talked about earlier, plus being used as targets for either an aircraft or a surface antiaircraft weapon. UAVs that are used as targets have, for many years, been called drones. Many people incorrectly call all UAVs drones.

UAVs vary in several ways. In size, they may be nearly as large as a conventional aircraft, they may be just a little larger than a model airplane (the kind you may see in the park) or they may be any size in between. Their propulsion device may be a reciprocating engine, a turbojet, a ramjet, a liquid- or solid-fuel rocket motor or even an electric motor. They may be steered in flight by radio signals, by onboard computers, by flight programs designed before takeoff, by self-contained navigational sensors or by combinations of these methods. They may be recoverable and reusable or they may be disposable. When recoverable, they may either land on their own or be snagged in midair by recovery planes or helicopters. They may be targets or they may deliver weapons to other targets. They may even fly high or low.

***Boeing X*-36 Unmanned Tailless Agility Research Aircraft** *(Boeing Photo)*

Key Terms and Concepts

- rotor system
- gearbox
- rotor hub
- rotor blades
- composite materials
- heavy-lift
- light-lift
- compound helicopters
- hybrid helicopters
- Short-Takeoff-and-Landing (STOL)
- Vertical-Takeoff-and-Landing (VTOL)
- Newton's 3rd Law of Motion
- Tilt-Rotor Research Aircraft (TRRA)
- Unmanned Air Vehicles (UAV)

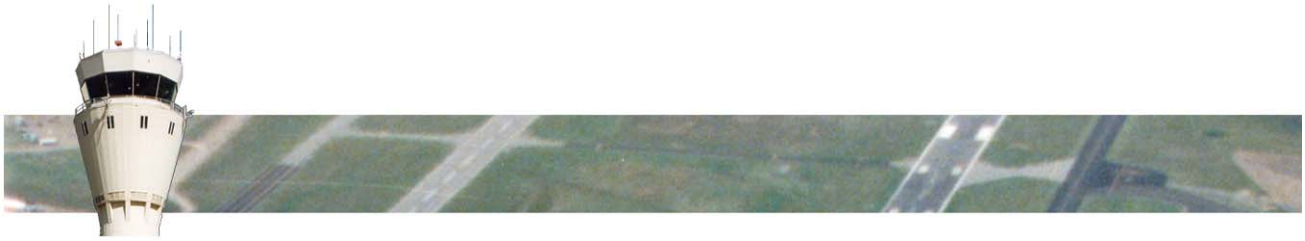
? Test Your Knowledge ?

SELECT THE CORRECT ANSWER

1. *The dividing line in the text for deciding whether a helicopter is heavy-lift or light-lift is a useful load of* **(4,000 / 5,000 / 6,000)** *pounds.*
2. *Generally speaking,* **(compound / hybrid)** *helicopters go further than (compound/hybrid) helicopters in combining the airplane and helicopter.*
3. *There is debate within the aerospace community whether (VTOL/STOL) will have much value after* **(VTOL / STOL)** *is fully developed.*
4. *UAVs have been in wide usage since the* **(Vietnam / Korean / Gulf)** *War.*
5. *The USAF standardized definition of STOL is an aircraft with the ability to clear a* **(50 / 100 / 200)** *foot obstacle within* **(1,000 / 1,500 / 2,000)** *feet of commencing takeoff role and to stop within* ***(500 / 1000 / 1500)*** *feet after passing over a (50/100/200) foot obstacle when landing.*

MULTIPLE CHOICE

6. *Which of the following was not a drawback to helicopters that has been improved or eliminated due to advancements in technology?*
   a. *High maintenance*
   b *High noise levels*
   c. *Controlability problems*
   d. *Slow cruise speeds*
   e. *Vibration*



7. *Which of the following is not a dominant foreign manufacturer of helicopters?*
   a. *Schweizer*
   b. *Aerospatiale*
   c. *Messerschmitt-Bolkow-Blohm*
   d. *Agusta*
8. *Which of the following is not a major US manufacturer of helicopters?*
   a. *Lockheed*
   b. *Boeing*
   c. *Bell*
   d. *Sikorsky*

FILL IN THE BLANKS

9. *The _____ is a _____ helicopter using a tilt-rotor designed developed for _____ US military.*
10. *By applying _____ (for every action, there is an equal and opposite reaction), VTOL capability is achieved.*
11. *Using the main propulsion units for VTOL requires either _____(like the AV-8) or _____ (like NASA TRRA).*
12. *UAV missions are classified as either _____ or _____, depending on whether or not the UAV is used to destroy a target.*

TRUE OR FALSE

13. *Although initially designed for military use, heavy lift helicopters are being used more frequently in the civilian market, mainly through military surplus sales.*
14. *The helicopter was first put into use after World War I.*
15. *Many helicopters are produced in both civilian and military versions.*
16. *A drawback to helicopters is their inability to accomplish a transoceanic flight.*
17. *In-flight aerial refueling has yet to be adapted for helicopters.*